PHYSICAL AND BIOLOGICAL IMPACT ON MARINE BENTHIC POLYCHAETES DUE TO DREDGING IN THE MORMUGAO HARBOUR, GOA AND ITS RESTORATION AFTER DREDGING

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Recolonization of benthos following dredging operations was studied in Mormugao Port Trust Harbour, Goa. Six stations were fixed for sampling within the radius of the dredging site. Three samples each were collected during dredging and after dredging. The proportion of gravel in the sediment of the dredged site increased after dredging, while that of organic matter decreased. The impact on community was estimated at species level, using both univariate and multivariate analyses. Maximum negative effect was observed during dredging where a reduction by 60-70% on macrofauna was evident. Within six weeks after dredging the density of the polychaete *Clymene annadalei* increased in the dredging site, while typical 'opportunistic' species such as *Capitella capitata* was not favoured by dredging. Favourable condition for resettlement of benthic communities is probably available in about four months.

Key words: Recolonization, dredging, benthos, harbour, impact

INTRODUCTION

Dredging operations in harbours are long-established human-induced disturbances. The impact of dredging is often considered to be similar to trawling as both are towed across the surface sediments where they are likely to damage the organisms near the surface (Morton 1977). These topographic changes persist longer in deeper and more sheltered waters, which are less exposed to wave action (Jones 1992). Impact of dredging/fishing has been well-documented; however, biological impacts are particularly difficult to investigate because of the complexity of benthic communities and our limited knowledge of its natural variability (Gislason 1994). Dredging reduces seagrass abundance and replaces the habitats to unvegetated sand flats (Peterson *et al.* 1987).

These anthropogenic perturbations usually drastically reduce the benthic population and temporarily change the environmental abiotic features (Pranovi *et al.* 1998). Spatio-temporal variations in abiotic and biotic parameters in this estuarine system are affected by tropical monsoon; riverine and tidal flows make them ecologically complex system (Harkantra 1975; Parulekar *et al.* 1980; Qasim and Sen Gupta 1981; Harkantra and Parulekar 1985; Rathod *et al.* 1991; Shetye *et al.* 1995)

Although the effect of dredging and disposal of dredged material have been relatively well-documented (Giovanardi *et al.* 1998; Lewis *et al.* 2001), subsequent recolonisation is a site-specific process, with both time and spatial scale involved. Further, recolonization depends upon the local hydrodynamic and sedimentary conditions (Guerra-Garcia *et al.* 2003). In most dredging instances, the magnitude and locations govern the impact of possible ecological disturbances. Existence of control sites with similar sediment characteristics, depth and benthic community to the dredge site is not always easy to find, and this restricts the accuracy of many studies.

The objective of this study was to examine the impact of dredging on benthic community, sediment characteristics, decolonization and possible reason to evaluate the effectiveness of recovery in a tropical harbour.

MATERIAL AND METHODS

The study area – Mormugao Port – is located at the mouth of river Zuari (15°25' N; 73° 47' E; Fig. 1). The harbour is located between two bays connected by a channel, which is 4.6 km long with increased water movements across and around the middle of the harbour. It is one of the six important major ports along the west coast of India. In early 1950, it handled limited cargo, whereas today major developmental changes have taken place and the harbour handles substantial quantities of cargo, ore and oil. It is characterized by intense shipping traffic, and frequent loading and dumping is involved in shipping operations. Existence of vast iron ore reserves in Goa helped to grow into a major export harbour having an annual traffic of over 14 million tons. The depth in the harbour ranges between 3 to 14 m.

The annual siltation in the channel, which mostly occurs during monsoon is about 34 lakhs cu. m. With the changes in shipping trends the approach channel requires to be deepened and continuously maintained to a desirable depth to cater to deep draft-vessels, such as oil tankers, bulk cargo vessels and ore carriers.

Table 1: Species density n/0.04 sq. m (average of triplicate samples) at different sites and months

Months/Polychaete species	Stations					
	1	2	3	4	5	6
April						
Prionospio pinnata	71.8	44	48	69	82	79.6
Clymene annadalei	23.7	21	64.6	3.9	13.3	55.6
Lumbriconereis sp.	1.3	0.4	0	0	0	0
Nephthys inermis	0.3	0	0.3	0	2.7	2
Nereis capensis	2.7	0	1.6	0	0	1.4
Megalona sp.	0	0	2.4	3.3	0	0
Capitella capitata	8.8	12.4	0	17.1	0	0
Glycera alba	0	0	3.4	0	4.7	2.1
Number of Species	6	4	6	4	4	5
May						
Prionospio pinnata	0.9	10	0	0	4	17
Clymene annadalei	0	4	0	0	2	8.7
Lumbriconereis sp.	0	0	0	4.8	0	0
Nephthys inermis	8.6	0	0.8	0	2.3	0.7
Nereis capensis	0	0.9	0	3.6	0	0
Megalona sp.	0	1.8	0	0	0	0
Capitella capitata	0	2.3	0	0	0.7	0
Glycera alba	0	0	0	0	0	2.4
Number of Species	2	5	1	2	4	4
June						
Prionospio pinnata	5	0	0	3.6	0	1.1
Clymene annadalei	1.9	0	0	0	2.8	4.9
Lumbriconereis sp.	0	0	0	0	0.4	0
Nephthys inermis	0	0.8	0	0.2	0	0
Nereis capensis	6.4	0	0	0	0	1.2
Megalona sp.	0	0.7	0	0	0	0
Capitella capitata	4.4	0	0	0	0	0.3
Glycera alba	0	0	3.9	0	0	0
Number of Species	4	2	1	2	2	4
August						
Prionospio pinnata	56.6	33	49.9	21.3	36.4	29.8
Clymene annadalei	56.2	56.6	29.4	91.4	104.4	91.6
Lumbriconereis sp.	2.3	15.2	0	0	1.1	0
Nephthys inermis	0.6	0	0.3	0	10.3	0
Nereis capensis	20.1	0	0	3.3	0.7	0.4
Megalona sp.	0	0	2.3	0	0	0
Capitella capitata	3.9	6.9	3.1	0	0.9	19.3
Glycera alba	0.6	0	0.3	3.6	0	0
Number of Species	7	4	6	4	6	4
October						
Prionospio pinnata	76.2	146.6	69.4	91.4	97.4	91.6
Clymene annadalei	66.6	93	79.9	71.3	36.4	29.8
Lumbriconereis sp.	4.3	15.2	0	9	1.1	0
Nephthys inermis	0.6	3.1	0.3	3.1	10.3	0
Nereis capensis	20.1	0	0	3.3	0.7	0.4
Megalona sp.	1.1	0	2.3	0	0.9	0
Capitella capitata	2.3	6.9	3.1	0	0	5.3
Glycera alba	0.6	0	0.3	3.6	0	1.1
Number of Species	8	5	6	6	6	5

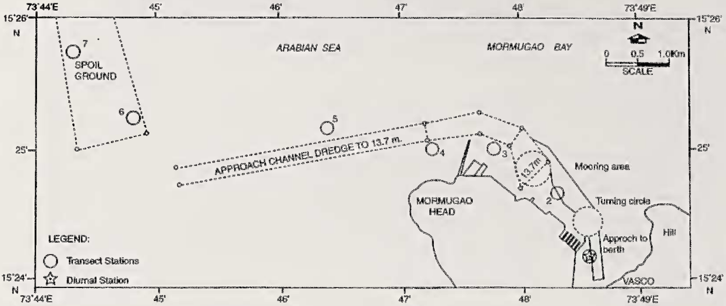

Fig. 1: Schematic diagram of the stations studied at Mormugao Port Trust Harbour

In the Mormugao Harbour, dredging was carried out in the approach channel, turning circle, and mooring buoy berths (Fig. 1). Port Authority began dredging soon after our first sampling (pre-dredging sample), i.e., at the end of April. Samples were collected before, during and after dredging between April and October 2009. Seven stations were fixed. Stations, 1-5 were within 100-200 m radius of the dredging area, and Station 6 and Station 7 at 5 km and 7 km respectively. The seventh station was a dumping yard. Samples collected in April were considered as baseline data. Three samples were obtained from each site with a van Veen grab; sediment penetration was never less than 20 cm. Sediment samples from the grab were preserved in 10% formalin in sea water and Rose Bengal stain mix. Later, these samples were sieved through 0.5 mm mesh size; samples retained on the sieve were transferred to plastic containers and preserved in 5% formalin in sea water (Eleftheriou and Holme 1984). Macrofauna were identified at species level and each species was counted under the stereo zoom microscope. Population density was converted to 0.04 sq. m. One grab was used for analyzing sedimentary characteristics and organic matter analyses following standard procedures. The organic matter obtained from samples of sediment previously dried at 100 °C over 24 hour, was analysed by ashing to 500 °C (Eleftheriou and Holme 1984). Granulometry was determined by Buchanan and Kain's method (Buchanan and Kain 1984).

Univarite analyses provided the total number of species, total abundance, Shannon-Weiner diversity and Pielou's evenness indices (Shannon and Weaver 1963; Pielou 1966), and the Margalef index (Margalef 1958). Using the values of the triplicates (0.04 sq. m), the possible variations of these community descriptors were tested with one-way ANOVA, after verifying normality using the Kolmogorov-Smirnov test and Bartlett test for homogeneity of variances.

RESULTS

The data for environmental parameters is presented in Fig. 2 a and b. The macrobenthic organisms because of their limited mobility form an important indicator of the prevailing environmental conditions in a locality. They play an important role in biogeochemical processes, pollutant metabolism, and secondary production (Snelgrove 1998). Earlier studies have suggested that benthic fauna of a dredged area differs from that of a non-dredged area with respect to species composition (Newell *et al.* 1998).

Table 1 shows spatio-temporal distribution of benthic polychaete species. The fauna was composed mainly of polychaetes and dominated by *Prionospio pinnata* followed by *Clymene annadalei*. During the present study, eight species were recorded among the local benthic fauna. Species density varied with sites and months; density of *Prionospio pinnata* 146.6/0.04 sq. m (station 2) being highest, which was recorded in October (Table 1). This indicates the small scale spatio-temporal heterogeneous variation of soft-bottom dwelling macro-invertebrates (polychaeta). This could be attributed to the perturbation in the environment due to dredging. The abundance, number of species, species richness, evenness and indices started to re-adjust 42 days after dredging (Figs 3 a-e). After dredging, polychaetes, especially *Clymene*

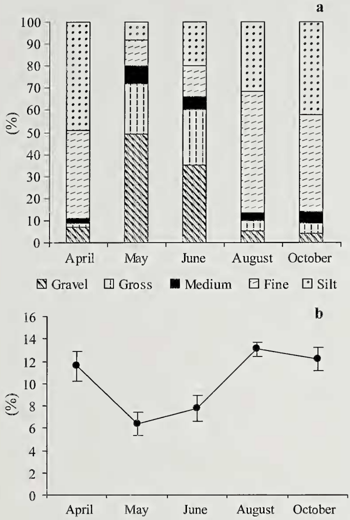

Fig. 2: (a) Sediment granulometry (b) organic matter
Values are averages of 6 samples taken during April-October. Median grain size ranges Gravel: 2 mm; gross-very gross sand: 0.2-2 mm; medium sand: 0.25-0.5 mm; fine-very fine sand: 0.065-0.25 mm; silt-clay: Me < 0.065 mm. Organic matter mean values with standard error.

annadalei, drastically increased in the dredged site, while opportunistic species, such as *Capitella capitata*, were present in low abundance (Table 1).

Table 2 represents species diversity index, evenness and richness. The result of two-way ANOVA between stations and species in different months (Table 2) showed significant differences for all variables. The result of 1-way ANOVA of macrofaunal abundance showed variation between sampling months and stations. Abundance of macrofauna was not very rich during May and June. A positive and significant relation between the species and non-significant relations between stations were found in April, August and October. April and October also show no significant variation indicating that the community has returned to pre-dredging values.

Table 2: F-ratios obtained through Two-way analysis of variance (ANOVA) between stations and between species

Months	April	May	June	August	October
Source of variation					
Between stations					
n_1=5	0.4	1.34	1.24	0.458	1.09
n_2=35	p> 0.05	p> 0.05	p> 0.05	p< 0.05	p< 0.05
Between species					
n_1=7	27	1.87	0.87	24.90	30.43
n_2=35	p< 0.001	p< 0.05	p< 0.05	p< 0.001	p< 0.001

DISCUSSION

This study documents the impact of dredging operations on a soft-bottom community by the changed sediment structure as well as by the depletion of organic matter. Dredging caused initial decrease in macrofaunal abundance, biomass and species number. Similar studies have been reported by Lopez-Jamar and Mejuto (1988) and Guerra-Garcia *et al.* (2003) from elsewhere. A number of species, especially burrowing polychaetes and fragile groups, such as nemerteans, were probably killed and cut by dredging. Others may have been affected by high turbidity, high rates of sedimentation, or were buried when depressions were filled (Black and Parry 1994). Due to these changes, species diversity and individuals reduced to 80-90%. As per Newell *et al.* (1998), diversity is expected to reduce by 30-70% and species abundance by 40-90%. In the present study, the macrofaunal community showed quick recovery (4 months). Recovery of lost community in a dredged area may take a few days to years depending upon the intensity of dredging, the hydrodynamic condition of the dredged area, sediment texture and macrofaunal community (Pranovi *et al.* 1998).

Changes in relative distribution of major benthic groups following dredging abatement have been noted earlier (Johnson and Nelson 1985; Hily and Glemarec 1990). However, these do not appear to follow a consistent pattern, and are presumably habitat and community specific. In addition, it has been noted that certain taxonomic groups appear to be more affected by dredging than other groups (Morton 1996), although this may be habitat, location and/or community specific.

Macrobenthic community was recorded after cessation of dredging. This is in contrast to many studies, which report a near complete defaunation in active dredging areas (Johnson 1981). The formation of undisturbed "hummocks" of undredged material during dredging have a high biological significance in the process of repopulation by the indigenous benthic community within the dredged area (McCauley *et al.* 1977). This recolonization results from the migration of adults or by larval establishment (McCauley *et al.* 1977). Zajac *et*

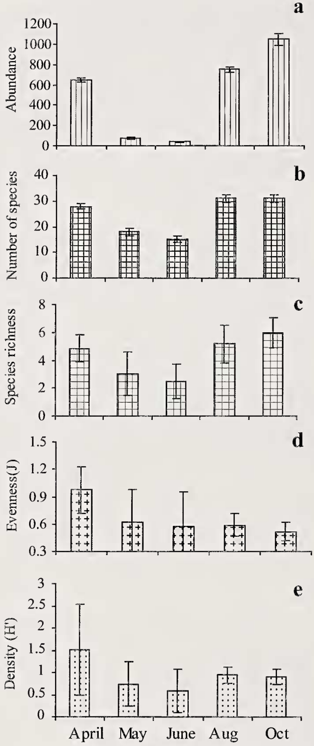

Fig. 3: Trend of abundance (a) species number, (b) species richness, (c) species evenness and species diversity (d) during different months during the study period. Mean values and standards errors are included

al. (1998) pointed out that the relative combination of factors controlling re-colonization and successional process may be different depending on the spatial scale.

Considering the fact that Mormugao harbour is tide dominated, with waters being well mixed, the benthic colonization was probably through water column (larvae and /or adults) (Guerra-Garcia *et al.* 2003). Further, cessation of dredging was followed by monsoon season which facilitated faster recolonization of the dredged site by the new recruit from the surrounding areas.

A variety of abiotic and biotic factors, including human perturbation (McCall 1977; Trueblood *et al.* 1994), affect the benthos. The community was represented by early colonizing species, such as the opportunistic Maldanidae polychaete *C. annadalei* and *P. pinnata*. A major structuring force in colonization of benthic fauna was the response of species to resources released from sediments by periodic disturbances (Rhoads and Boyer 1982). Biotic habitat modification by earlier species may also enhance the settlement of subsequent species, which suggest the facilitative mechanism of succession that can occur in soft-bottom communities (Zajac *et al.* 1982). Tropical monsoon in estuaries brings about defaunation and drop in salinity triggers reproduction in most benthic organisms followed by recruitment during post monsoon season (Harkantra and Rodrigues 2003).

The polychaete *Capitella capitata* is one of the most common species known to be highly tolerant to polluted areas. It can also be considered as one of the global opportunistic species in disturbed marine sediment (Estacio *et al.* 1997; Newell *et al.* 1998). In the present study, the species was present in less abundant after dredging. The changes in sediment characteristics and reduction in organic matter, could have affected recolonization of *C. capitata*. Changes to community structure caused by dredging were smaller and allowed quick re-adjustment of the initial sediment structure and benthic communities.

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